Overview of the AUREP: Advanced University Reciprocating Engine Program

Presented by
Dr. Bryan Willson, Colorado State University
on Behalf of the
Academic Advisory Board
of the AUREP

Peer Review of ARES Reciprocating Engine Program
DOE Distributed Energy Peer Review
Washington, D.C.
December 2-3, 2003

Outline

- The AUREP Research Program
- Selected Results to Date
- The Academic Advisory Board
- Academic / Industry Linkages

ARES Program Goals & Barriers

Program Goals:

Efficiency:

50% electrical generation efficiency

Emissions:

0.1 gm/kw-hr NOx

Economics:

reduce life-cycle cost of power generation by 10%

Barriers:

Identified through:

- Roadmapping workshops
- Industry consultation
- Precompetitive research efforts

Used to guide university solicitation

Initial focus areas:

- Improved ignition for high-bmep lean-burn engines
- Reduced mechanical friction
- Improved exhaust aftertreatment

University Reciprocating Engine Research

Managed For
Office of Power Technologies/Office of Energy Efficiency and Renewable Energy

Tom J. George, DOE/NETL Project Manager
Ronald Fiskum, DOE/EERE Program Sponsor

COOPERATIVE AGREEMENT with TEN UNIVERSITIES

$6,4712,000 Total Contract Value ($5,392,700 DOE)

12 AUREP Projects: 10 direct, 2 "special status"

- **Fundamental Studies of Ignition Processes in Large Natural Gas Engines Using Laser Spark Ignition**
  Colorado State University
- **Low Engine Friction Technology for Advanced Natural Gas Reciprocating Engines**
  Massachusetts Institute of Technology
  Colorado State University
- **Ignition Improvement of Lean Natural Gas Mixtures**
  Michigan Technological University
- **Two Stage Catalytic Reduction of NOx**
  Ohio State University
- **Corona Discharge Ignition for Advanced Stationary Natural Gas Engines**
  University of Southern California
- **Reduced Engine Friction and Wear**
  University of Texas at Austin
- **Rail-Plug Ignition System for Enhancing Engine Performance and Reducing Maintenance**
  University of Texas at Austin
- **Advanced Natural Gas Reciprocating Engine: Parasitic Loss Control Through Surface Modification**
  Purdue University
- **Selective NOx Re-Circulation for Stationary Lean-Burn Natural Gas Engine**
  West Virginia University
- **Energy Thermal Management via Active Flow Control**
  University of Tennessee
- ***Improvement to Pipeline Compressor Engine Reliability Through Retro-Fit Micro-Pilot Ignition System**
  Colorado State University
- ***Catalyst Studies**
  University of Maryland

*Special status – funded through other DOE programs

5 AUREP Ignition Projects

Goal: To help overcome ignition-induced barriers to high efficiency, high reliability, and low emissions

Special status:
Funded through other DOE programs

5 AUREP Ignition Projects

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5 AUREP Ignition Projects

University of Southern California

Corona Discharge Ignition for Advanced Stationary Natural Gas Engines

Paul D. Ronney, Principal Investigator, USC/AME

Tom J. George, Project Manager, DOE/NETL

Ronald Fiskum, Program Sponsor, DOE/EERE

COOPERATIVE AGREEMENT DE-FC26-02NT41336

Awarded 4/1/03, 36 Month Duration

$710,491 Total Contract Value ($560,491 DOE)

5 AUREP Ignition Projects

The University of Texas

Railplug Ignition System for Enhancing Engine Performance and Reducing Maintenance

Ron Matthews, Principle Investigator
(Matt Hall and DK Ezekoye, Co-PIs)
Tom J. George, Project Manager, DOE/NETL
Ronald Fiskum, Program Sponsor, DOE/EERE

COOPERATIVE AGREEMENT DE-FC26-01NT41334

Awarded 9/30/01, 36 Month Duration
$670,481 Total Contract Value ($491,460 DOE)

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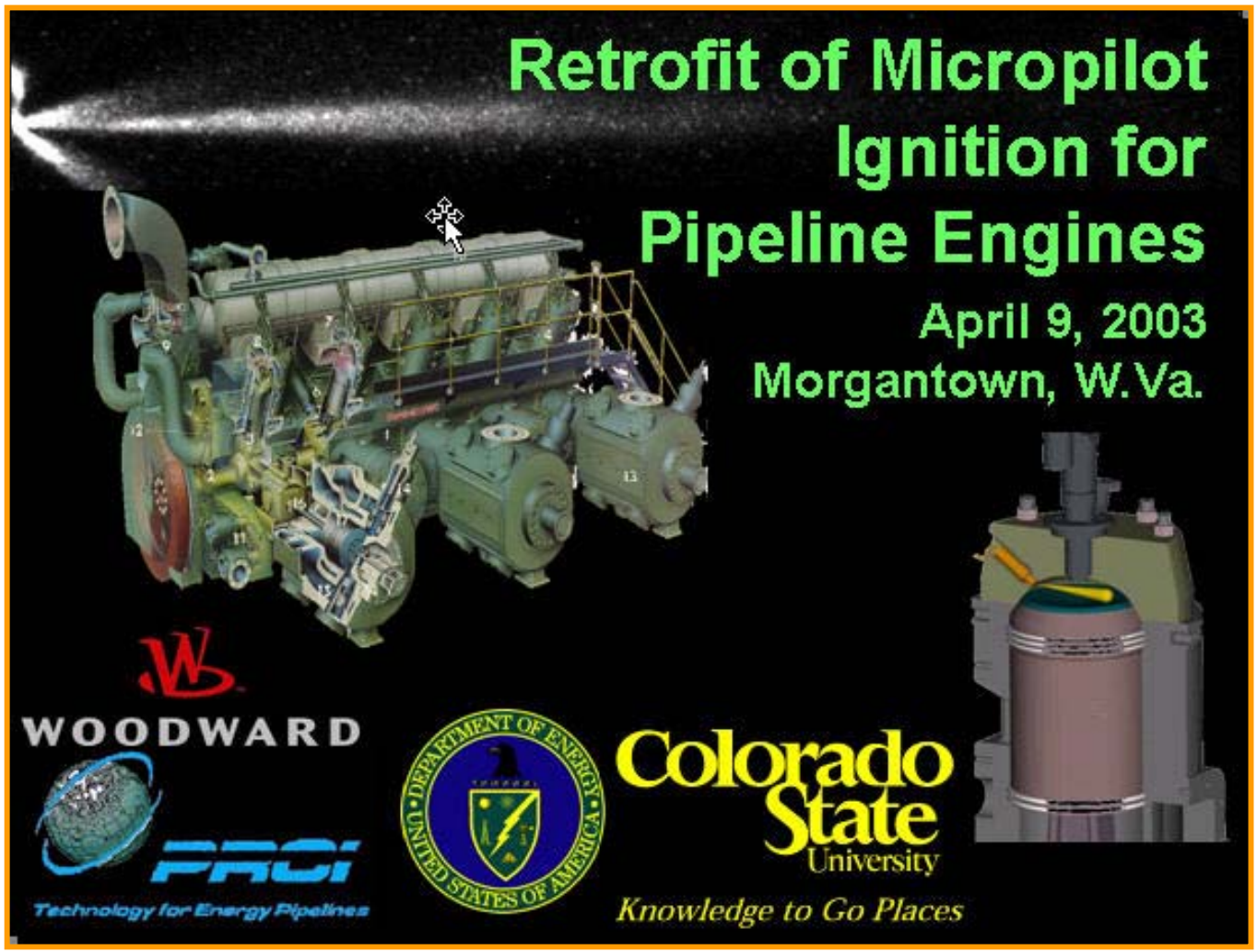
5 AUREP Ignition Projects



Special status:
Funded through DOE Natural Gas Infrastructure Program

3 AUREP Friction Projects

***Goal*: To help increase engine efficiency by overcoming friction-induced parasitic losses**

3 AUREP Friction Projects

Massachusetts Institute of Technology

Low Engine Friction Technology for Advanced Natural Gas Reciprocating Engines

Victor W. Wong, Principal Investigator, MIT

Tom J. George, Project Manager, DOE/NETL

Ronald Fiskum, Program Sponsor, DOE/EERE

COOPERATIVE AGREEMENT DE-FC26-02NT41339

Awarded April 1, 2002 (24 Month Duration)

$910,068 Total Contract Value ($ 728,063 DOE)

3 AUREP Friction Projects

Purdue University
Parasitic Loss Control Through Surface Modification

Principle Investigator: Farshid Sadeghi, Ph.D.

Tom J. George, Project Manager, DOE/NETL

Ronald Fiskum, Program Sponsor, DOE/EERE

COOPERATIVE AGREEMENT DE-FC26-02NT41340

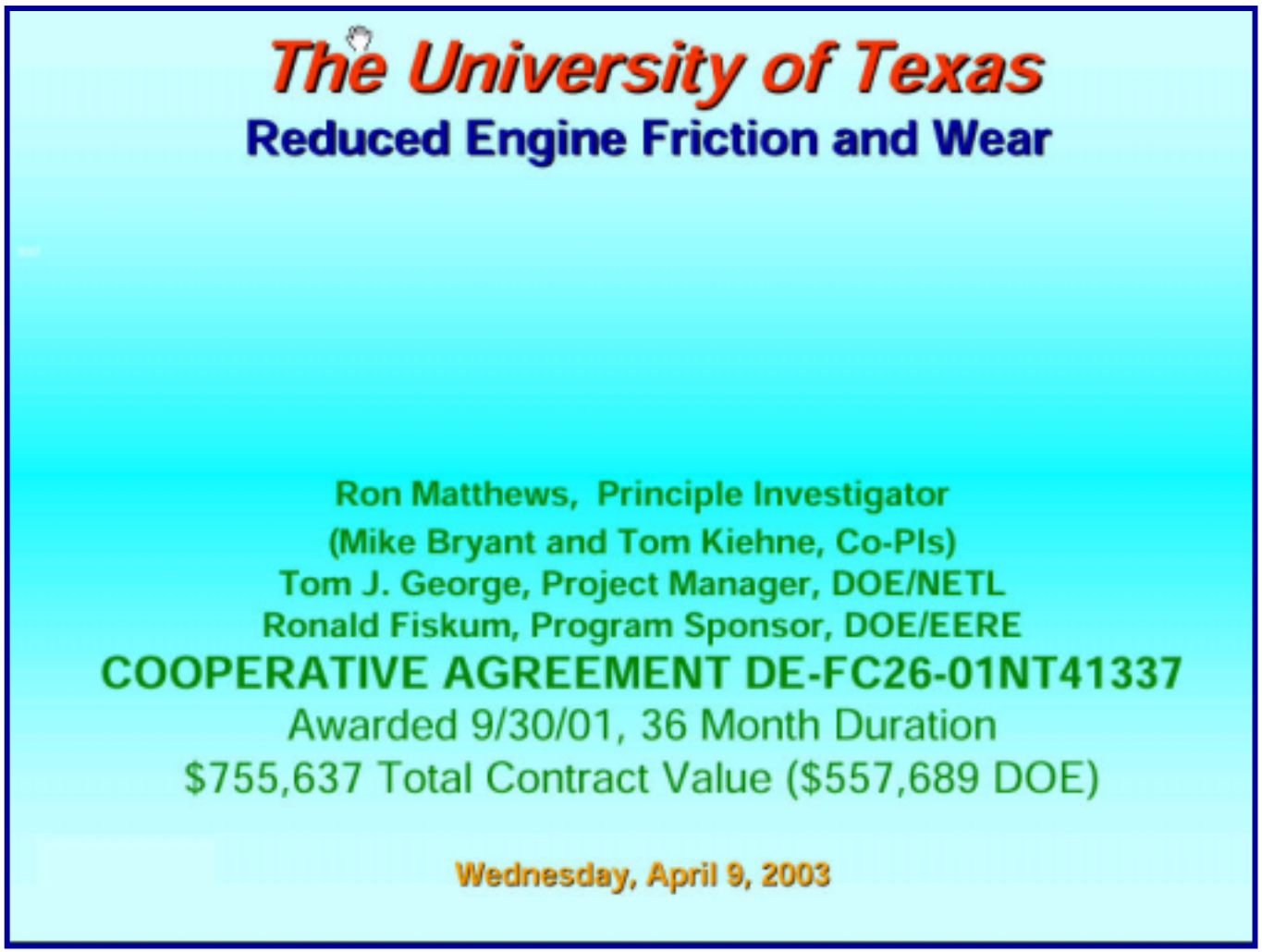
Awarded (4/1/2002, 36 Month Duration)

Total Contract Value: $575,317 - DOE Share: 459,41

Purdue Cost Share: $115,903

Purdue University *Tribology Laboratory*

3 AUREP Friction Projects



4 AUREP Aftertreatment Projects

Goal: To support ARES emissions goals by removing barriers to effective aftertreatment

University of Maryland

Principal Investigator
Dr. Greg Jackson

Special status:
Funded through other
DOE programs

4 AUREP Aftertreatment Projects

West Virginia University
Where Greatness is Learned

Selective NOx Recirculation Project

Principle Investigator
Tom J. George, Project Manager, DOE/NETL
Ronald Fiskum, Program Sponsor, DOE/EERE
Industrial Partner
Sorbent Technologies Corporation
Project Team
Dr. Nigel Clark, Dr. Gregory Thompson,
Ralph Nine, Krishna Aravelli, Chamila Tissera

COOPERATIVE AGREEMENT DE-FC26-02NT_41608
Awarded (10/01/2002, 36 Month Duration)
$749,913 Total Contract Value ($599,287 DOE)

4 AUREP Aftertreatment Projects

The University of Tennessee

Energy Efficient Thermal Management of Natural Gas Engine After treatment Via Active Flow Control

Principle Investigators

David K. Irick

Ke Nguyen

Tom J. George, Project Manager, DOE/NETL

Ronald Fiskum, Program Sponsor, DOE/EERE

COOPERATIVE AGREEMENT DE-FC26-02NT41609

Awarded (10/01/2002, 36 Month Duration)

$750,000 Total Contract Value ($600,000 DOE)

4 AUREP Aftertreatment Projects

Ohio State University

Two-Stage Catalytic Reduction of NOx

Umit S. Ozkan, Principle Investigator

Tom J. George, Project Manager, DOE/NETL

Ronald Fiskum, Program Sponsor DOE/EERE

COOPERATIVE AGREEMENT DE-FC26-02NT41608

Awarded (10/1/02, 36 Month Duration)

$760,321 Total Contract Value ($600,930 DOE)

DOE-NETL
4/9/03-USO

4 AUREP Aftertreatment Projects

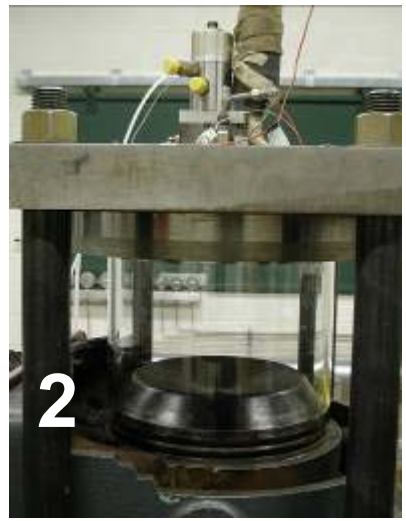
University of Maryland

Principal Investigator
Dr. Greg Jackson

Special status:
Funded through other
DOE programs

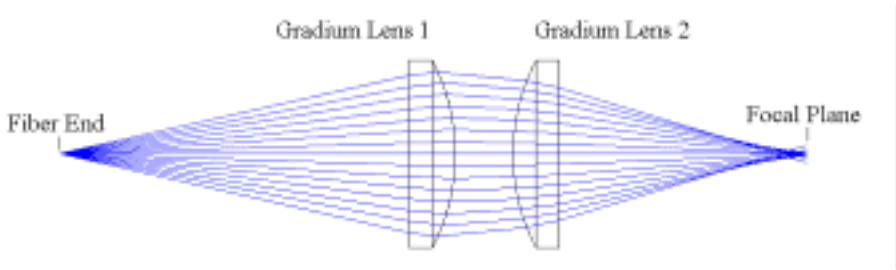
Selected Results: CSU Laser Ignition (1/3)

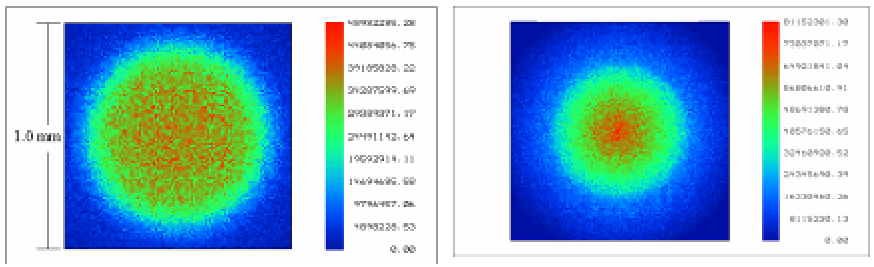
- **Original tasks:**
  1. Combustion test chamber studies
  2. Optical engine studies
  3. On-engine studies
  4. Implementation issues, including fiber optic delivery
- **Program developments**
  - Complementary programs also initiated at DOE labs: NETL & Argonne
  - Fiber optic delivery more difficult than originally thought

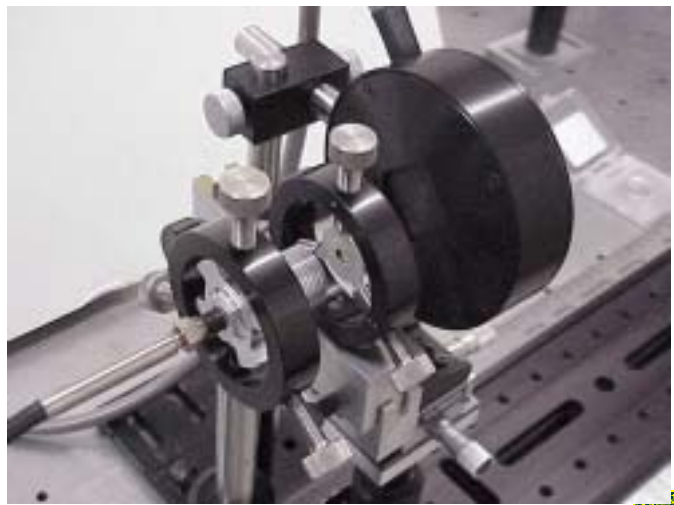


Selected Results: CSU Laser Ignition (2/3)

- Some redundancy in optical engine & single cylinder experiments with DOE labs
- Potential major obstacle with fiber optic beam delivery
- Project was refocused to move fiber optic delivery to an earlier high-priority task
- Additional investigators brought in from diverse interdisciplinary groups at CSU
- Partnership formed with another national lab (Oak Ridge National Lab) for optical modeling support
- Several alternative approaches identified

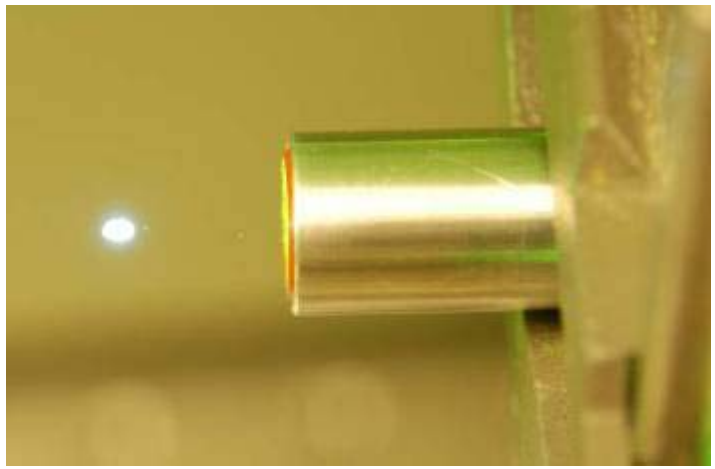




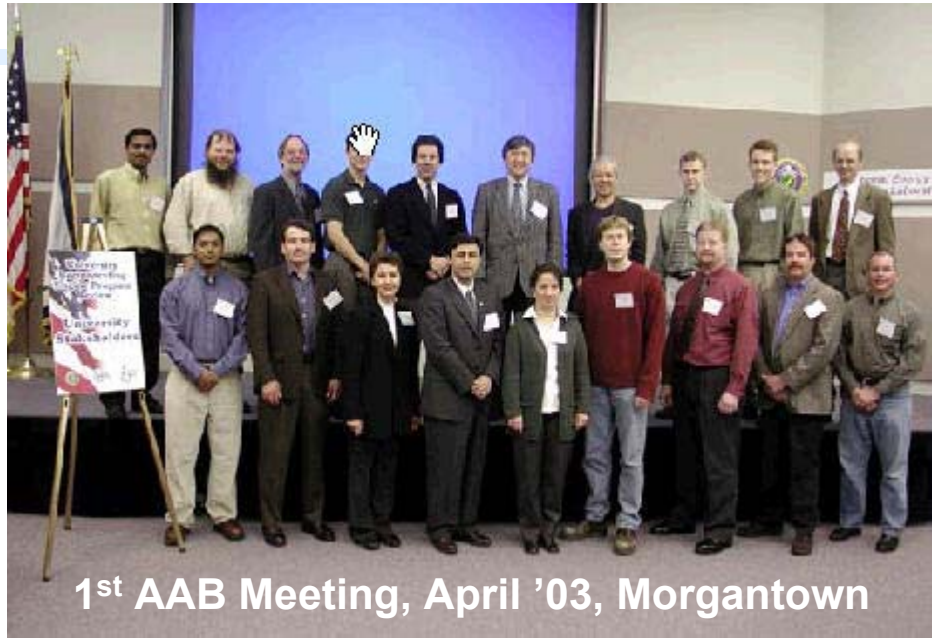


Selected Results: CSU Laser Ignition (3/3)

- Initial success with fiber optic beam delivery achieved on 11/6/03
- Further fiber optic concepts being evaluated
- Program will move directly to abbreviated CTC phase then on-engine
- Engine installed for the project can support other DOE on-engine tests, if desired



Academic Advisory Board: Motivation & History


1st AAB Meeting, April '03, Morgantown

- ARES manufacturers work together to "speak with one voice" on issues of common interest
- University program could be similarly enhanced through coordinated communication
- Program began informally with DOE Ignition Workshop in November '02
- Groundwork by steering committee in January '03
- Program formalized at organizational meeting in April '03

Academic Advisory Board: Goals

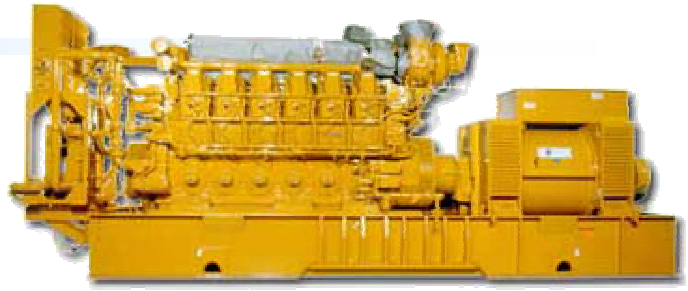
- Facilitate education of university research community on broader engine issues, outside of focused research specialty
- Provides DOE a conduit for University expertise and opinions on critical issues facing engine research and development
- Assists DOE in identifying research needs
- Enhances credibility and generality to University program by establishing standard test conditions and metrics

Academic Advisory Board: Accomplishments

- **Have provided technical support for 4 specialized DOE/Industry topical workshops on:**
  - Ignition systems: CSU
  - Friction / Efficiency: MIT, Purdue, Univ. of Texas, CSU
  - Catalysts / Aftertreatment: Ohio State, Maryland
- **Convened organizational meeting in April '03**
- **Drafted standard testing conditions / metrics for:**
  - Standard in-cylinder conditions for ignition & friction studies
  - Standard exhaust composition conditions for aftertreatment studies
- **Convened 2-day workshop on ARES-type natural gas engines November 19 & 20**
- **Working with DOE & industry group on implementing an industry internship program**

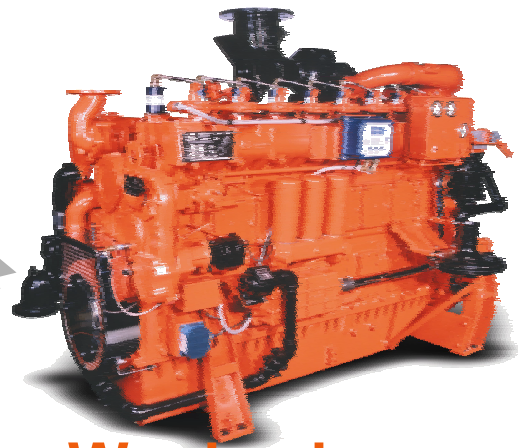
Academic / Industry Linkages

- Focused technical exchange during 4 DOE Technology Roundtables
- 1-on-1 industry / university exchange on individual projects
- Formal overview during University review
- Enhanced student interaction through new internship program



Caterpillar

Cummins



Waukesha

Academic / Industry Linkages Educational Benefits

- Most of the 12 projects utilize 2-3 graduate research assistants; many utilize additional undergraduate assistants
- Projects provide “real-world” research experiences for students
- Program provides a valuable source of high-quality engineering talent to the U.S. distributed generation industry